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Irina Subbotina, Alexander Buevich, Alexander Medvedev, Alexander Sergeev, Marina Sergeeva, Helen Kazakova, Alexandra Kosachenko, and Anastasia Moskaleva

Statistical Analysis of the Spatial Distribution of Impurities in the Snow Cover in the Vicinity of Copper Mine in the Middle Ural of Russia

Irina Subbotina[2, a)], Alexander Buevich[1,2, b)], Alexander Medvedev[1,2, c)], Alexander Sergeev[1,2, d)], Marina Sergeeva[2, e)], Helen Kazakova[3)], Alexandra Kosachenko[1)], and Anastasia Moskaleva[1)]

[1]*Ural Federal University, Mira 19, Yekaterinburg, Russia, 620002*
[2]*Institute of Industrial Ecology UB RAS, Sophy Kovalevskoy 20, Yekaterinburg, Russia, 620990*
[3]*Donetsk National Technical University, Artem 58, Donetsk, Ukraine, 83015*

[a)]iesub@mail.ru
[b)]bagalex3@gmail.com
[c)]Corresponding author: alnikmed52@gmail.com
[d)]aleksandrpsergeev@gmail.com
[e)]marin@ecko.uran.ru

Abstract. Statistical analysis of the monitoring data of industrial enterprises influence zones is an important part of the researches related to natural environment changes. In present study, a cluster analysis of the elemental composition of the snow cover in the vicinity of a copper mine was carried out. The data were obtained as a result of the chemical analysis of the snow samples collected during annual environmental monitoring in the region of Rezh town (the Middle Ural of Russia), where Safyanovsky Copper Mine and Rezhevsky Nickel Plant are located. The elements identified by chemical analysis were grouped according to the strength of the correlation bond. The cluster analysis of these groups made it possible to identify and separate the influence zones of the Plant, Mine and other industrial objects located in the area. The obtained results became the basis for adjusting the snow cover monitoring scheme.

INTRODUCTION

One of the important problems in the environmental studies is the development of monitoring data analysis methods to obtain new knowledge on the environment. Environmental monitoring is a complex system of observation, assessment and forecasting of changes in the state of the environment. In the last century, the main tasks in the work with environmental information were: conducting of observations, accumulation of data, as well as their storage and structuring. These tasks were solved with the development of the computer technology, databases and management systems. Today, the problem of extracting of useful knowledge from existing and new databases comes to the fore. This knowledge may be presented in the form of regularities, rules, forecasts, relationships between the data elements. The main tool for finding new knowledge is data mining technologies, which solve the tasks of analysis and interpretation, as well as prediction of possible environmental changes.

There are a lot of modern methods for data analysis. For example, in the researches of snow cover pollution we successfully used the models based on the land use regression [1] and artificial neural networks [2].

This paper considers the possibilities of cluster analysis in above mentioned studies.

Cluster analysis identifies homogeneous groups of the data items if the grouping is not previously known. Since it is a search engine, it does not distinguish between dependent and independent variables. Different methods of the cluster analysis can handle nominal, ordinal and scale (interval or relative) data. For example, the "K-means cluster"

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is the method for quickly clustering of large data sets. The researcher defines the approximate number of clusters in advance. The belonging of the objects to clusters is determined in such a way as to minimize the variability within the clusters and to maximize the variability between them. This is useful to test the different models with the different assumed number of clusters [3-7, 9, 10].

MATERIALS AND METHODS

Snow is a natural substance, which is widely used in environmental monitoring. During the formation of snow cover and during the snowfall, the concentration of pollutants in snow becomes in 2-3 orders of magnitude higher than in the ambient air as a result of wet and dry washing-out processes. This allows determining the content of pollutants in snow with high accuracy using the samples with a weight of 3-4 kg. Low temperatures ensure the safety of chemical compounds throughout the season. Snow covers the surface of the soil, so the secondary pollution caused by the raising of dust decreases. In this regard, the particles that are in the air in the winter have a predominantly technogenic origin, therefore, the mimic composition of snow cover reflects its technogenic pollution (as well as technogenic pollution of the atmospheric air). To obtain a picture of the spatial distribution of the pollutants on the territory, it is necessary to take samples during the maximum accumulation of moisture reserves in snow (late February-early March) [3].

In present study, the cluster analysis of elementary composition of snow cover near a copper mine and a nickel plant was carried out in order to separate the areas of their influence on the environment. The data were obtained as a result of the chemical analysis of snow samples taken during the annual monitoring in the region of Rezh town, Middle Ural, Russia in 2015, 2016 and 2018. In each of these years, 47 samples of the snow were taken in the direction of the prevailing west-south-west winds from the pipe of the Nickel Plant (Rezh) towards the Safyanovsky copper mine and further to Zabolotye village, located 7 km west-southwest of the mine. The region of the Safyanovsky copper-pyrite deposit is under the torch of emissions from the Rezhevsky nickel plant. The plant is melting nickel ore on three shaft furnaces to produce nickel matte. The plant was suspended in January 2017 due to difficult market conditions. The monitoring area is shown in Fig. 1 and the sampling points' location is shown in Fig. 3. The selected snow samples were melted and filtered, an accredited laboratory carried out a chemical analysis of the solid and liquid phases.

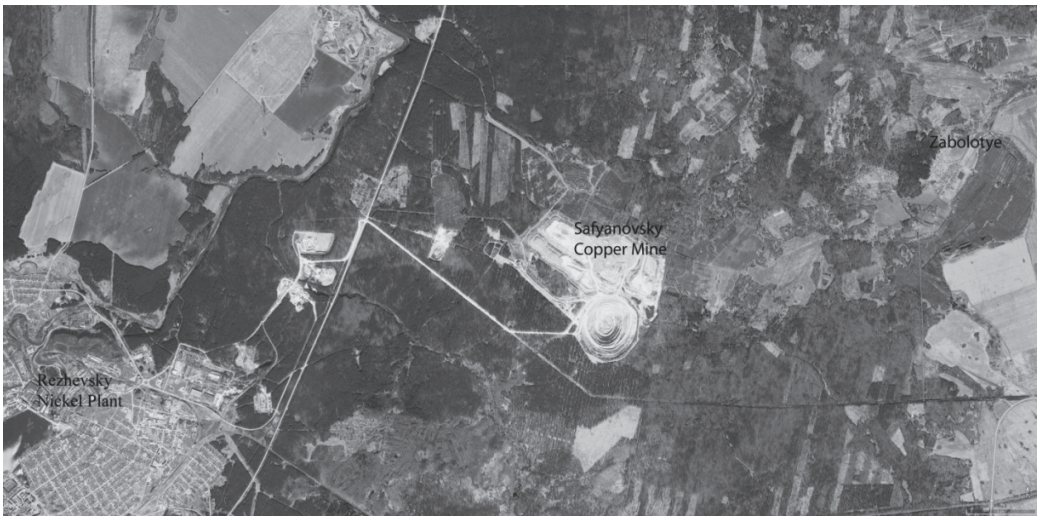


FIGURE 1. The monitoring area (© Google Earth).

Sampling for this study was carried out at the end of the winter before the snowmelt on the entire thickness of the snow cover, so the results of the chemical analysis show the content of pollutants averaged over the time of the snow cover existence. As an indicator of pollution we use the intensity of pollutants accumulation, which reflects the average amount of pollutants dropped with the snow per unit area during winter season.

RESULTS AND DISCUSSION

The choice of the cluster analysis parameters for determining the zone of the influence of the emissions of the Rezhevsky Nickel Plant was carried out on the basis of an analysis of the graph of correlation galaxies constructed in [6]. The strongest links (correlation coefficient 0.98 and 0.96 with p-level <0.05) were found between the contents in the snow of nickel and manganese, arsenic and aluminum. This is because the elements are in the compounds formed as a result of the same processes, and are the part of the pollutants from the same source. However, the aluminum content also strongly correlates with the copper content (correlation coefficient 0.84 with p-level <0.05 [6]), so using it as a parameter of the cluster analysis leads to the incorrect results. Scattering diagrams were constructed to check for the correlations between the content of the elements in the snow samples taken in 2015, 2016 and 2018. Figure 2 shows the dispersion diagrams for the content of nickel, manganese and arsenic in the samples date in 2015 and 2018. The results for 2016 are similar to those obtained for the data for the year 2015. It is seen that in 2018, the correlation between the nickel content and the manganese content decreased, and the association of the nickel content with the arsenic content practically disappeared. We can assume that this is due to the termination of the Rezhevsky Nickel Plant in the winter of 2017.

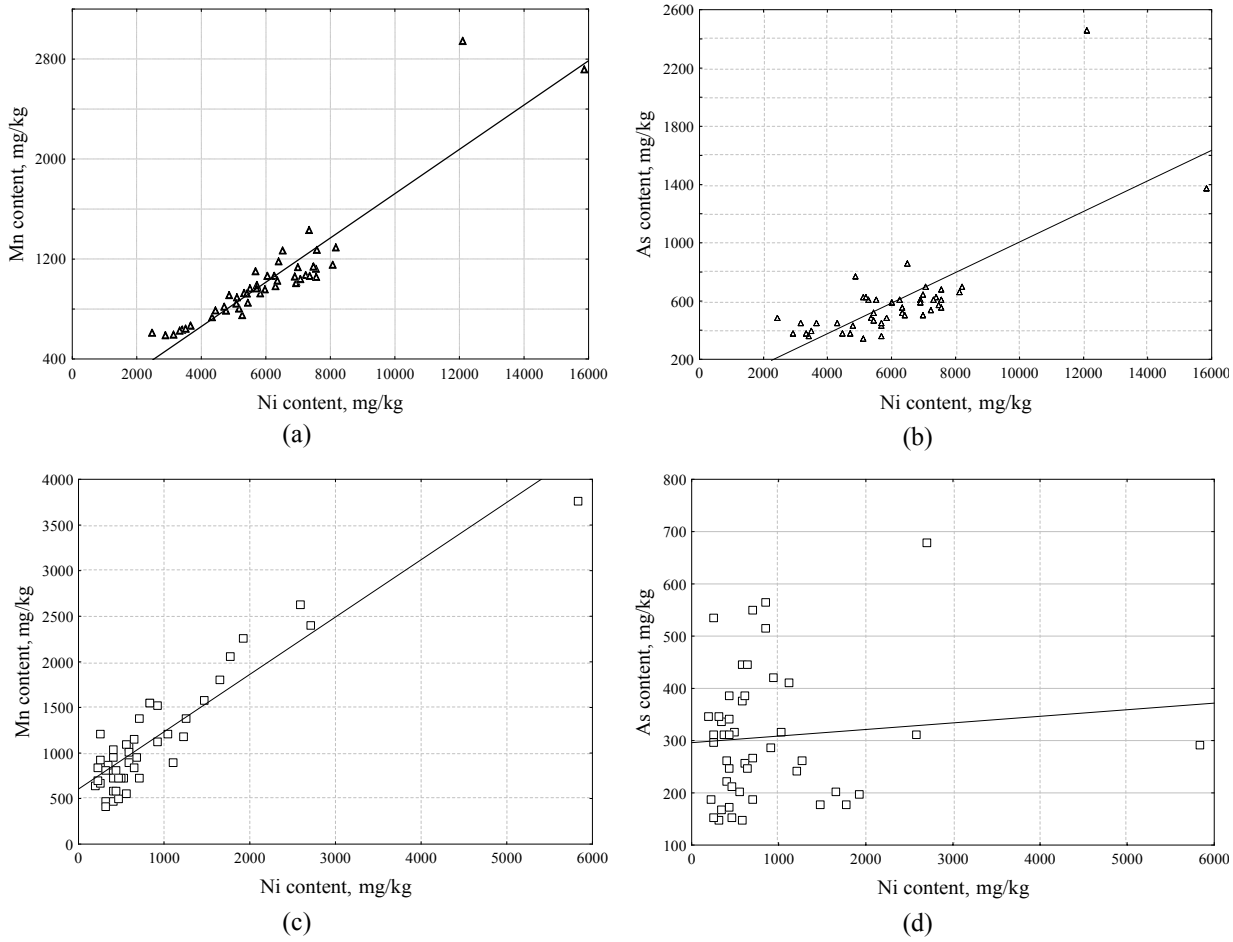
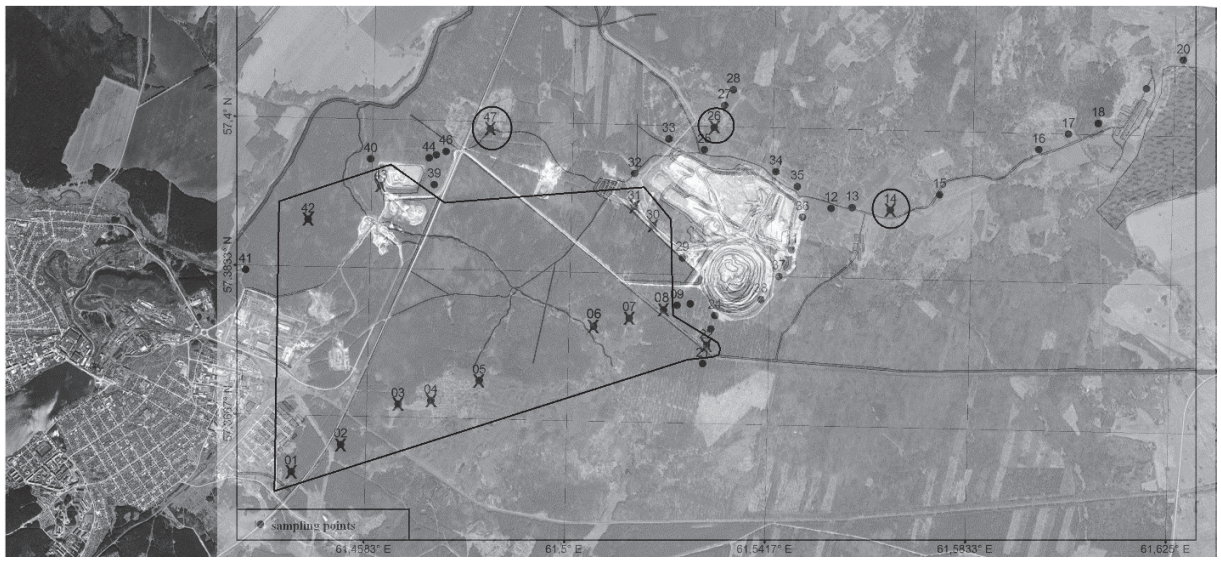


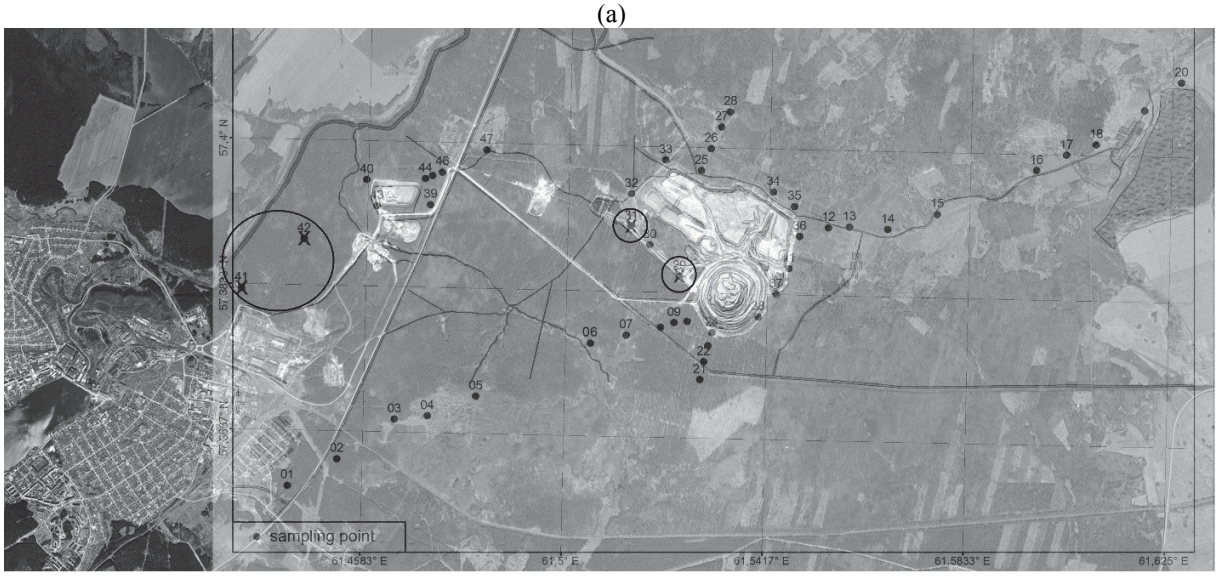
FIGURE 2. Diagrams of the dispersion (triangles are used for 2015 (a, b), squares - for 2018 (c, d)).

This assumption is also confirmed by the results of the cluster analysis. If, according to the data from 2015 and 2016, explicitly allocated spatial clusters are formed from the sampling points located on the leeward side of the Rezhevsky Nickel Plant pipe, in 2018 sampling points assigned to one cluster are randomly distributed throughout

the study area. The results of the cluster analysis for the data of 2015 and 2018 are illustrated in Fig. 3; the picture obtained for 2016 is similar to Fig. 3a.



(a)



(b)

FIGURE 1. The results of the cluster analysis for the 2015 (a) and 2018 (b)

CONCLUSION

The cluster analysis of the elemental composition of the snow cover near the copper mine and the nickel plant was carried out according to the data obtained from the chemical analysis of the snow samples taken during the annual monitoring of the environment in Rezh town area, Russia in 2015, 2016 and 2018. According to the data of 2015 and 2016, clearly identified spatial clusters of sampling points are formed. In 2018, after the termination of work of the Rezhevsky nickel plant, the sampling points assigned to one cluster are randomly distributed throughout the study area. Thus, it can be concluded that the cluster analysis can be used to separate the areas of influence on

environment of the industrial enterprises located in the same territory. The results of this study became the basis for adjusting the snow cover monitoring scheme in the area.

ACKNOWLEDGMENTS

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